Repellents: Projections of Direct Benefit-Cost Surfaces

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Abstract: Iterative (1 variable-changed-at-a-time) Lotus 1-2-3® spreadsheet calculations were used to derive hypothetical benefit:cost ratios (BCRs) based on the recommended-use patterns for a commercial turf repellent (Rejex-It®) to deter Canada geese from grazing/loafing on golf fairways and for a commercial shrub/plant repellent (Deer I Repellent®) to deter deer from browsing on landscape shrubbery. Scenarios were based on "real-world" costs of products and valuations of resources. Plots of the BCR-response surfaces for Rejex-It® on fairways showed that BCRs for these turf applications ranged between 63.9 and 0.73. These BCRs showed transitivity, with highest to lowest BCRs linked with revenues from 90+ foursomes per day, 28-day spray intervals, 3.34 ha of fairways, and a $2.00/ha application cost versus 45+ foursomes/day, 7-day spray intervals, 10.24 ha of fairways, and a $10.00/ha application cost, respectively. A plot of BCRs for using Deer I Repellent® based on replacement outlays for shrubs yielded BCRs between 47.12 and 0.52. This response surface yielded transitivity within shrub-size/-number classes and had enhanced "scallop;" all BCRs for 6 and 12 spray applications involving 10-40 shrubs, 0.305-1.122-m radius plants, and 20-100% damage were $\geq$2.27 (i.e., more than double the cost outlays for the chemical). Although requiring a number of assumptions, our approach provides useful decision-making aids for persons interested in the economics of wildlife damage management methods. The main advantage is that projections of the combinations of variables associated with the potential "break-even" point (BCRs =1.0) for these interventions are available *a priori*, and that scenarios can be modified with relative ease to view the benefit-cost impacts of other input variables or model assumptions.

Key Words: repellents, benefits, costs, goose, deer, Rejex-It®, Deer I Repellent®

INTRODUCTION

Many specific and generic compounds allegedly exert some olfactory, gustatory or irritant effects upon animals (see Mason 1997); some of these compounds are marketed commercially to deter wildlife damage of crops, resources, or property (e.g., Rejex-It®, Deer Away® Big Game Repellent). Although questions of efficacy exist for most repellent products, we were impressed by the relative lack of studies concerning the economics associated with recommended-use patterns of these compounds.

Sterner (2002) and Sterner and Lorimer (2001) described an *a priori* approach to examining the benefits-costs of performing damage-management activities to reduce agricultural and resource losses caused by wildlife. Spreadsheet software (e.g., Lotus 1-2-3®, Excel®) was used to compute iterative outputs of benefits and costs linked with the use of a registered rodenticide (zinc phosphide) for vole control in alfalfa; mean annual production yield and price served as the basis for net savings. Tabular and graphical displays of these BCRs afforded useful decision-making aids regarding the likely "break-even" conditions for baiting to reduce vole damage in alfalfa. Savings less than application costs were projected for crop losses $\leq$8%.

This paper extends the use of spreadsheet analyses to the potential benefits and costs of applying commercial repellents in defined wildlife damage situations. Two hypothetical scenarios are developed: Use of a turf repellent (Rejex-It®) to deter goose grazing/loafing on golf fairways and use of a plant repellent (Deer I Repellent®) to deter deer browsing on landscape (ornamental) shrubbery.

METHODS

Approach

Environmental economics involves making valuations of hard to quantify benefits and costs associated with natural resources (Field 2001). Wildlife damage to resources such as endangered species predation, livestock disease transmission, and mountain stream contamination can be viewed as causing losses of "full" resource or resource-use value. Techniques of wildlife damage management offer ways of reducing or preventing these losses.

Repellents represent one form of wildlife-damage-management technology, with many issues of efficacy, habituation, and economics unresolved. Perhaps their main advantage is the potential for non-lethal, socially-accepted mitigation of wildlife damage.

Essentially, 6 parameters determine the benefits-costs of repellents: (1) resource value, (2) amount of damage, (3) cost of the technique (i.e., product, personnel and equipment), (4) area or volume of application (product expended), (5) frequency of application (i.e., duration or persistence of the effect), and (6) effectiveness of the protection (i.e., efficacy within application). Our approach was to program hypothetical resource-repellent scenarios involving prescribed variables of these parameters using Lotus 1-2-3®, 9.5 software (Lotus Development, Cambridge, MA). Repeated runs of the programmed formulas, with one variable changed at a time, allowed us to compute and plot resultant BCRs associated with the many combinations of variable inputs. Use of actual pricing data and recommended application rates of repellents provided "real-world"

estimates of a repellent's potential under a described scenario. Computed BCRs were then plotted as 3-dimensional graphical displays to show these economic response surfaces.

Econometric Model

The econometric model is relatively straightforward. An estimate of maximum resource value was viewed to be the potential golf revenues that could be garnered from the resource or the potential shrub replacement value that would be required if damage was unchecked. The following equations define the model:

$V_{max} = R \times P$

where V_{max} is maximum value of the resource ($), R is resource use or quantity, and P is price/unit ($/unit).

$S_{max} = V_{max} \times D \times E$

where S_{max} is maximum savings of the resource ($) that can be recouped by damage intervention, V_{max} is defined above, D is expected wildlife damage (%), and E is expected repellent efficacy (decimal).

$C = Repel + Pers + Equip$

where C is the combined Repellent [Repel = (Area × $/Repellent Rate)], Personnel [Pers = (Area × $/Unit Area)], and Equipment [Equip = ($Maintenance, $Purchase, or $Rental)] costs. Repel refers to a specific management tool, and was based on commercial prices charged for the quantities needed according to a chemical registration (label) or recommended-use guideline; these estimates were the product of the area (ha) times the price/unit/area (e.g., ha × $/L/ha, $m^2 \times$ $/L/$m^2$). Pers was either included as an input variable if paid application of repellent was involved (i.e., $/ha for the personnel charge × ha) or eliminated if labor was assumed to be provided by a homeowner. Equip was based on either the rental or pro-rated purchase price for a specific applicator device (e.g., hand-held sprayer, granular spreader, mixing and cleanup costs for a commercial sprayer).

$BCR = S_{max} \div C$

where BCR is a relative quotient of direct savings to direct costs, and S_{max} and C are defined above. Independent estimates of S_{max} and C are derived.

The term direct is important here. "Direct" benefits and costs are distinguished from "indirect" and "induced" values which entail more subtle forms of benefits and costs that can accrue to the revenue and repellent-use situations (e.g., indirect benefits-costs of easements to attract wildlife away from some habitat, induced benefits-costs of having wildlife analyzed for disease to reduce public health risks, etc.).

Assumptions

A main assumption inherent to our approach is that S_{max} represents a continuous variable. In reality, this variable could be discrete, with a certain magnitude of wildlife damage required before a threshold of intolerance is attained and some action (i.e., lost revenue) is undertaken. Secondly, we make no attempt to validate the wildlife damage or the repellent efficacy estimates; these are simply assumed to represent a portion of the total resource valuation that would be lost by inaction and recouped by product performance. Although this is a contentious assumption, we argue that the effectiveness of a wildlife-damage-management method is assumed to yield savings of that portion of potential revenues that would otherwise be lost without applying a repellent–effectiveness of the management tool is an input variable used to reflect hypothetical efficacy of the product or method. Despite the complex interactions among chemical, species, applicator, and field conditions (e.g., compound efficacy, population densities, weather conditions), the capability to vary and observe the consequences of these inputs is a key advantage of our approach.

Data Analysis

Results were treated descriptively. Graphs of the computed BCRs were plotted and "zones" of ratios ≤1.0 (parity of C and S_{max}) were delineated.

SCENARIO I: REJEX-IT® ON GOLF FAIRWAYS AS A GOOSE REPELLENT
Problem

Urban populations of Canada geese (*Branta canadensis*) have grown dramatically in many regions of the U.S. (Conover and Chasko 1985, Williams and Bishop 1990). Although a valuable viewing resource for the public, these large populations of geese pose problems for park and golf course managers. Dense fecal droppings by geese detract from the public's enjoyment of the recreation.

The chemical methyl anthranilate (CAS-134-20-3) has been shown to deter grazing and loafing of geese (Cummings et al. 1991, Cummings et al. 1992, Cummings et al. 1995). This chemical is currently marketed as Rejex-It® AG-36 (e.g., Martin-Nicholls, Inc., Willoughby, OH). Scenario I projected BCRs for potential mitigation of goose-caused losses with this repellent.

Details of the Scenario and Spreadsheet Code

Lotus 1-2-3® spreadsheet code was programmed to derive V_{max} for potential revenues at a local public golf course; this entailed computing the revenues for estimated numbers of rounds and solving for potential losses incurred due to geese. In 2001, a summer greens fee was $46.00/18 holes (peak summer daytime fee), with a $25.00/9-hole fee offered at the end of each day (i.e., 5:30 pm - 7:00 pm – until dark). Tee-offs were scheduled every 8 min. during peak times (i.e., 7.5 foursome rounds/hr between 5:30 am and 5:30 pm, and 7.5 twosomes assumed to occur between 5:30 pm - 7:00 pm). Thus, a peak day was estimated to produce $17,122.50/day revenues {[(7.5 foursomes/hr × 12 hr) + (7.5 twosomes/hr × twosomes × 1.5 hr)] or 360 18-hole + 22.5 9-hole rounds = [(360 × $46.00) + (22.5 × $25.00)] = $16,560.00 + $562.50}. This revenue was also halved in a series of analyses to reflect a "less than peak" situation

($8,561.25/day revenue)– a typical weekday or less profitable golf revenue.

Three different size areas were considered for repellent application. A typical fairway was roughly 100 × 400 yds (3.34 ha); we then doubled (6.68 ha) and tripled (10.02 ha) this area to simulate 2 or 3 fairways. This was a main input variable.

Goose-caused damage was reasoned to be reflected in lost revenues. That is, "perceived," unacceptable density of goose fecal droppings would be associated with an arbitrary 4, 8, 12, 16, or 20% decline in golfer use (greens fees) either by "word-of-mouth" or unwillingness of "regulars" to play the course. Maximum revenues would be decreased by these amounts.

Repellent application ($/ha) costs were adjusted for prescribed fairway sizes and for quantities of repellent needed to meet recommended application rates. The respective labor charge of $2, 4, 6, 8, and 10/ha was an input variable and the cost associated with each charge was computed separately. An arbitrary $50.00 fee for sprayer maintenance and mixing was also added to each application cost computation.

Chemical persistence (i.e., days between applications or duration of repellent effect) was included by coding the computations for 7, 14, 21, and 28-day intervals. That is, V_{max} was adjusted for these intervals based upon the product of daily revenues and days until re-application.

Effectiveness of the repellent was coded to reflect 1.0, 0.9, 0.8, 0.7, 0.6, and 0.5 potential savings of lost revenues for the prescribed days of repellent activity (spray intervals).

Thus, a total of 3,600 iterative combinations of the 2 revenue (90+ and 45+ foursomes), 3 area (3.34, 6.68, and 10.02 ha), 4 spray interval (7, 14, 21, and 28 days), 5 damage (4, 8, 12, 16, and 20 %), 5 personnel cost ($2, 4, 6, 8, 10/ha), and 6 effectiveness (0.5, 0.6, 0.7, 0.8, 0.9, and 1.0) variables were estimated using the computational formulas outlined above.

Example Calculation:
3.34 ha; 7-Day Interval; 4% Loss of Golfers; $2.00/ha Labor; 1.0 Efficacy

Rejex-It® = $69.95/gal (product cost varied; we selected a median price; see www.nixalite.com, www.bugpage.com, www.rejex-it.com) 2.5 gal/ac (advertised application rate).

Fairway of 400 yds. × 100 yds = 40,000 yds² ÷ 4840 yds²/ac = 8.26 ac

Converting to metric: 40,000 yds² × 0.836 = 33,440 m²; 10,000 m² = ha; 33,440 m² ÷ 10,000 m² = 3.34 ha typical fairway.

2.5 gal/ac × 3.3785 L/gal = 9.4625 L/ac ÷ 4046.85 m² or 23.38 L/ha application rate; $69.95/gal ÷ 3.785 L/gal = $18.48/L or $432.06/ha cost of Rejex-It®.

(1) V_{max} = $17,122.50/day × 7 days = $119,857.50.
(2) S_{max} = $119,857.50 × 4% × 1.0 = $4794.30 loss (or $684.90/day).
(3) C = {[3.34 ha × $2.00/ha] + [3.34 ha ×

$432.06/ha cost of Rejex-It®] + [$50.00 fixed set-up and sprayer fee] = [$6.68 + $1443.08 + $50.00]} = $1499.76.
(4) BCR = $4794.30 ÷ $1499.76 = 3.20.

Results and Discussion

Plots of the response surfaces for Rejex-It® on fairways showed that BCRs for these turf applications ranged between 63.9 and 0.73 (Figure 1). The BCRs displayed transitivity– greater revenues ($), higher expected goose-caused losses (%), longer spray intervals (days), smaller fairway areas (ha), and lower personnel costs ($/ha) yielded consistently greater BCRs. Highest BCRs occurred with revenues of 90+ foursomes/day ($17,122.50), 28-day spray intervals, 3.34 ha of fairway, $2.00/ha personnel cost, and 1.0 (complete) effectiveness of the product; whereas, lowest (negative) BCRs occurred for inputs associated with 45+ foursomes/day ($8,561.25), 7-day spray intervals, 10.24 ha of fairway, $10.00/ha application cost, and 0.5 effectiveness of the product, respectively.

Within either series of "90+ foursome" or "45+ foursome" calculations, delineation of the BCRs ≤1.0 (parity for invested costs versus possible green fee savings) showed similar (relative) patterns of transitive effects. As goose-caused losses declined (20% to 4% damage), persistence of the chemical declined (28 to 7 days between applications), area of sprayed turf increased (3.34 to 10.02 ha), personnel application costs increased ($2.00 to $10.00/ha), and hypothetical efficacy of the repellent decreased (1.0 to 0.5), BCRs of ≤1.0 "spread" to include more of the combinations of input variables (Figure 1). This "zone" of parity for investment-return started with revenue losses of 4%, then spread laterally along both X (% loss and personnel application costs $10.00 to $2.00) and Z axes (0.50 to 1.0 efficacy; 7 to 28 days persistence).

A key result that can be gleaned from these response surfaces is the rapid decline in BCRs for the more modest revenues linked to 45+ foursome/day fees ($8561.25/day) and the increased ha of fairway requiring spray application (Figure 1). Spraying multiple fairways (6.68 and 10.02 ha) in the 45+ foursome case cut BCRs dramatically relative to the 90+ foursome/day revenue case. Spraying repellent on 10.02 ha required at least a partial goose-deterrent effect to last 2 weeks for even marginal BCRs of 2.0 to occur– a doubling of potential savings for offsetting product application costs. Conversely, goose-caused losses ≥16% with 2 weeks persistence invariably yielded multiple BCRs (i.e., ≥2 times the costs of investments).

Some slight "scalloping" of the BCR surfaces occurred. This was associated with mainly the personnel cost and product effectiveness variables, and was attributed to the selection of input variables. Relatively large, abrupt changes in input variables caused uneven shifts or even retracing of BCRs to overlap other combinations of variables. That is, higher personnel costs and lower effectiveness proved relatively more or less expensive than prior combinations of inputs at intersections of selected loss and spray interval variables within each of the fairway and revenue plots. The
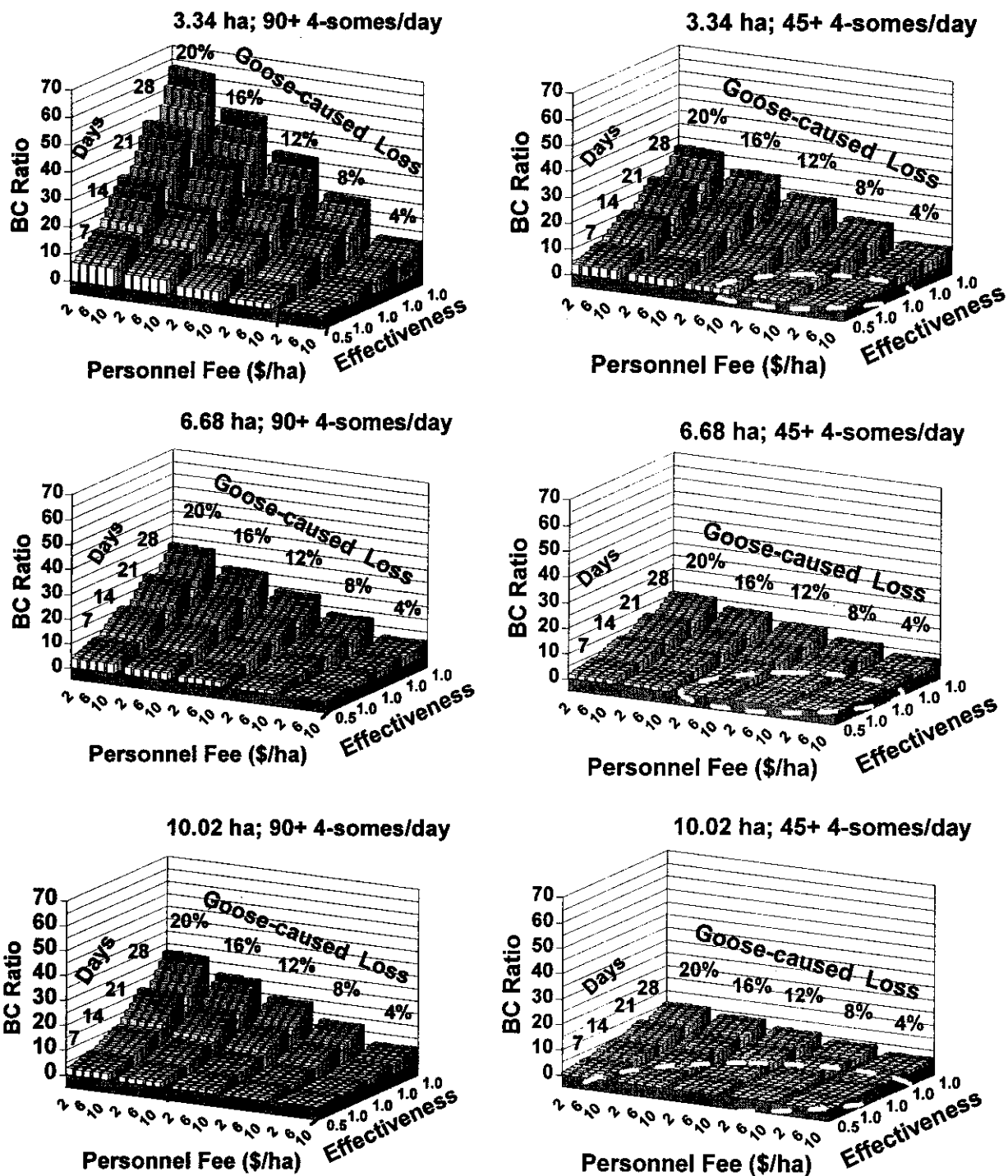
Figure 1. Series of 6 benefit-cost-ratio plots for applying Rejex-It® to 3.34, 6.68 and 10.02 ha of fairways with revenues for 90+ (left: top-bottom) and 45+ foursomes/day (right: top-bottom). [Note— Black-line and white-ellipse portions of plots show approximate variable inputs yielding BCRs = 1.0 or parity on investment returns].

effect was attributed to the compensatory effect that improved efficacy and lowered labor costs can exert on BCR.

The persistence of a turf repellent poses real-world economic issues for golf course use. A previous survey of U.S. golf course superintendents indicated that $60.00/ha would be a realistic expenditure to avert Canada geese (Cummings et al. 1991). Our scenario shows that current costs equal $432.06/ha, with equipment-mixing/-dispensing costs excluded; and, current calculations point out the need to assess the cumulative revenues gained between repeated applications of the repellent (likely returns/monetary outlays).

At the very least, our spreadsheet computations show that a more cost-effective turf repellent for park golf-course scenarios is probably needed. The rapid decline in BCRs for both 90+ and 45+ foursome scenarios as area of application increased to 10 ha despite cost effectiveness with greater than 12% goose-caused damage showed that high returns on investments would be unlikely for treatments of even 4 or 5 typical fairways. A "present-value" estimate (3%/annum inflation) of the superintendents' $60.00/ha, 1991 survey result translates to a 33% ($19.80/ha) increase or estimated $79.80/ha for current goose-management "willingness to pay." This -$352.26/ha cost disparity, coupled with high-volume irrigation (daily) and frequent mowing (every 3-4 days) regimes used at most golf facilities, offsets the utility of this turf repellent in the current price range in all but a few small-area (e.g., lake-edge, green) uses.

SCENARIO 2: DEER I REPELLENT® AS A SHRUB-BROWSE DETERRENT
Problem

Wild deer (*Odocoileus* spp.) are known to damage ornamental shrubs in many parts of the U.S. (e.g., Craven and Hygnstrom 1994, Decker and Gavin 1987, Sayre and Decker 1990). Although chemical repellents afford mixed efficacy for preventing deer from browsing on shrubs/plants, this technology continues to receive wide acclaim as a potential, non-lethal, socially-accepted approach to resolving homeowner complaints of deer damage.

For our purposes, we selected Deer I Repellent® (Deerbusters, Frederick, MD) as a candidate deer shrub repellent (http://www.deer-busters.com). The product description for this product lists putrescent egg, garlic, and hot pepper as ingredients– a repellent based on a combination of odor and tactile cues to induce animal avoidance; purchase costs and area coverages are fairly representative of this type of repellent product.

Details of the Scenario and Spreadsheet Code

Four parameters composed this scenario's inputs: (1) numbers of shrubs (10, 20, 30, or 40), (2) size of shrubs (0.305, 0.610, 0.915, and 1.220-m radius or 1, 2, 3 and 4-ft. radius), (3) deer-caused damage (20, 40, 60, 80, and 100%), and (4) spray frequency or persistence (6, 12, 24, and 52/yr)– effectiveness was not included, per se, but was indirectly dealt with via the input variable for spray frequency. Size of shrub was assumed to involve homogeneous-shaped plants with the surface area derived as a sphere (i.e., $4\pi r^2$); thus, the

0.305, 0.610, 0.915, and 1.220 m-radius shrubs had 1.169, 4.676, 10.52, and 18.704 m^2 surface areas, respectively. We designated approximate prices for 0.305, 0.610, 0.915, and 1.220 m-radius shrubs to be $50, $100, $200, and $400, respectively.

Lotus 1-2-3® spreadsheet code was programmed to derive V_{max} for potential replacement costs associated with typical evergreen shrubs (e.g., yews, spreaders) as offered at a local nursery. Key formulas for this scenario were:

(1) V_{max} ($) = Shrub Price ($)× Number of Shrubs (#)
(2) S_{max} ($) = V_{max} × Deer-caused Lost Shrubs (%)
(3) Cost ($) = [Surface Area Sprayed (m^2) × Repellent Price ($/$m^2$) × Sprayings (#/yr)] + $1 (sprayer life assumed to be 52 sprayings)]. [Note– This scenario considered personnel charges as non-existent since the product is offered to homeowners for application; homeowner efforts to both apply the repellent and replace the shrubs were considered "landscape maintenance."]
(4) BCR = S_{max} ($) ÷ Cost ($).

Computation of V_{max} for 10, 20, 30, and 40 shrubs having 0.305 ($50) m-radius yielded $500, $1000, $1500, and $2000. Similarly, the V_{max} for 10, 20, 30, and 40 shrubs was $1,000, $2,000, $3,000, $4,000 for 0.610 m-radius shrubs; $2000, $4000, $6000, and $8000 for 0.915 m-radius shrubs; and $4,000, $8,000, $12,000, and $16,000 for 1.220 m-radius shrubs, respectively.

Specific combinations of the 10, 20, 30, and 40 shrubs having 1.169, 4.676, 10.52, and 18.704 m^2 surface areas each yielded 16 different m^2 total areas for spraying (e.g., 10 × 1.169 m^2 = 11.69 m^2; 20 × 1.169 m^2 = 23.38 m^2). This was a main input variable.

Deer-caused damage was viewed as a per cent of shrubs that would have to be replaced at respective prices for the varied-sized shrubs. That is, damage of 20% for 10 shrubs having 0.305 m-radius ($50 each) would yield a loss of 2 plants or a $100 replacement cost.

Repellent application ($/$m^2$) costs were adjusted for prescribed total shrub surfaces and for the quantity of chemical that was recommended to deter browsing. The product charges, plus an arbitrary $1 pro-rated charge for wear on a hand-held liquid sprayer accounted for homeowner outlays.

Chemical persistence (days between applications or spray interval) was simply input to reflect a 6 (1 per 2 mo), 12 (1/mo), 24 (2/mo), and 52 (1/wk) per year application.

Example Calculation:
10, 0.305m-Radius Shrubs; 2-month Interval; 20% Damage; 1.0 Efficacy

Deer I Repellent = $165.95/gal ÷ 3.3785 L/gal = $49.12/L ($165.95/gal concentrate– no shipment charge due to order >$50); advertised application rate = 1 gal treats 12,000-16,000 ft^2 of plant surface (14,000 ft^2 chosen arbitrarily for calculations) or 14,000 × 0.093 = 1,302 m^2/gal or 385 m^2 /L or $49.12 /L ÷ 385 m^2/L = $0.13/$m^2$.

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Shrubs were spherical-shaped evergreens (surface area = $4\pi r^2$); all shrubs in landscape were the same size, with surface area based on numbers of shrubs = $10 \times (4 \times 3.1416 \times 0.305^2 = 1.169\ m^2) = 11.69\ m^2$ for 10, 0.305 m-radius shrubs. ($52 sprayer pro-rated at $1/use; no personnel application fees—homeowner applications and replacement of shrubs).

(1) V_{max} = $50/shrub × 10 shrubs = $500
(2) S_{max} = ($500 × 20%) × 1.0 = $100
(3) C = [(11.69 m^2 × 6 sprayings × $0.13/$m^2$) + $6 sprayer]
(4) BCR = $100 ÷ $15.12 = 6.61

Results and Discussion

The plot of 320 BCRs associated with the combinations of variables in the Deer I Repellent® Scenario yielded maximum and minimum values of 47.12 and 0.52, with extensive "scalloping" and a departure from transitivity for 1.122 m-radius shrubs (Figure 2). Highest BCRs occurred for bi-monthly (6) spray applications of 40, 0.305 m-radius shrubs with 100% loss due to deer browsing; lowest (negative) BCRs occurred for inputs associated with 52 applications of the repellent on 10, 0.915 m-radius shrubs with 20% deer-caused damage. Magnitude of BCRs generally decreased as the frequency of spray application and shrub size increased, but as number of shrubs and deer-caused damage decreased.

"Scalloping" of the BCR function was greater for this scenario—a result attributed to the "coarse" selection of input variables. The relatively large, 20% changes in inputs for deer-caused damage produced overlapping BCRs for combinations of variables at these junctions. Selection of more finely-graded damage inputs (e.g., 5%, 10% intervals) would yield a more uniformly altered set of BCRs.

A departure from transitivity occurred for combinations of the input variables associated with 1.122 m-radius shrubs. The price structure of applying the repellent to these larger surface area shrubs yielded a modest increase in benefits relative to costs; this is evident in the slight inverted shape of the BCR plots for these variables (Figure 2).

A major shift in the direct benefits of using Deer I Repellent® was evident between 24 and 52 applications per year; bi-weekly sprayings (at most) were crucial to recouping multiple benefits on invested dollars in all but extreme cases of deer-caused damage (≥0.80). All BCRs for 6 and 12 spray applications involving 10 - 40 shrubs, 0.305 - 1.122 m-radius plants, and 20 - 100% damage were ≥1.27 (i.e., exceeded the cost outlays for the chemical).

In one of the most thorough series of tests to date, Nolte and Wagner (2000) compared over 20 commercial deer repellent products in enclosure tests with black-tailed deer (*Odocoileus hemionus*), concluding that products which emitted sulfurous odors generally induced the most prolonged browsing avoidance (multiple weeks) of Western red cedar seedlings. Other reports have questioned the cost effectiveness of repellents, particularly deer-browse

repellents (Mason 1998). Current results illustrate the difficulty of developing cost-effective browse repellents for ungulates; chemical persistence of 2 weeks and extreme damage seem to be required to warrant intervention under the current price structure.
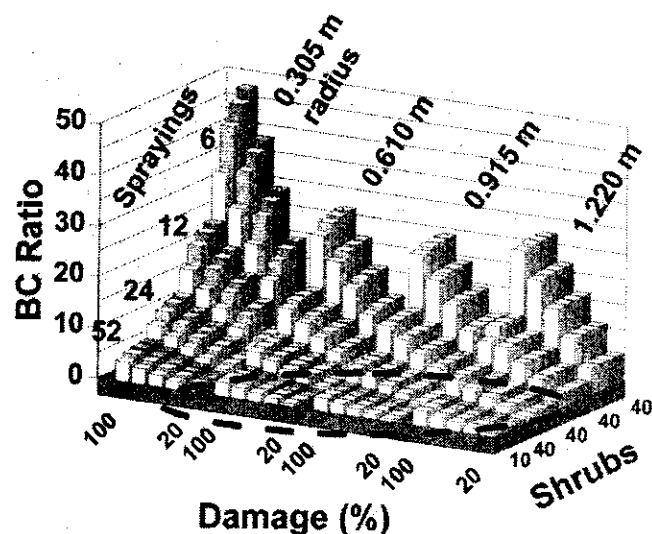

Figure 2. Plot of benefit-cost ratios based on replacement costs for applying Deer I Repellent® to 10, 20, 30, or 40 shrubs of 0.305, 0.610, 0.915, and 1.220 m radius. [Note– Black-ellipse shows approximate zone of BCRs ≤1.0.]

CONCLUSIONS AND WILDLIFE MANAGEMENT IMPLICATIONS

The utility of our spreadsheet approach to the *a priori* assessment of fiscal scenarios involving wildlife damage management techniques is demonstrated by the current results. Despite many assumptions, the approach affords a relatively inexpensive way to estimate economic outcomes of diverse wildlife-human-conflict scenarios via computer projections—an "arm chair" approach to examining the benefits and costs of repellents, toxicants, or other tools in diverse wildlife-damage situations. Outcomes of the turf-repellent scenario showed that garnering $8,561.25/day in course revenues yielded marginal cost-effective applications at current market prices unless goose-caused losses were ≥12%, fairway-use areas were ≤10 ha, and spray intervals were ≥14 days. The shrub-repellent scenario showed that multiple savings on cost outlays generally occurred between 24 and 52 applications per year; repellent use (persistence and efficacy) had to be kept to bi-weekly applications for the consistent recouping of multiple savings on investments. Future research and development will entail set up of interactive software to allow queues of users and inputs of diverse wildlife damage variables (avoidance of detailed spreadsheet coding by users), with the addition of response-surface analytical procedures to better identify key inflection points or vectors of BCR outputs.

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